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THE CONDITION OF STEEL IN BRIDGE PINS.

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WITH DISCUSSION.

The engineer who receives a report of a large number of tests from plates, angles and other shapes used in his bridge, which indicates an excellent material, may naturally suppose that his bridge pins, made under the same specification, and perhaps from the same casts of steel, are of the same excellent quality. That such is not the case will be demonstrated.

A few years ago it was customary to accept bridge pins, and also other material, on the result of a test made on a specially rolled ¾-in. round rod. The apparent simplicity and convenience of this method of testing was what led to its adoption, but it did not take long to demonstrate its inconvenience, and the fact that the steel was often in finished shapes before the test rods were rolled. This resulted in the substitution of tests from the finished material, with or without the round tests as a matter of record, and this substitution soon dem-

onstrated that a small round test was not an accurate indication of the condition of steel in other shapes.

Very naturally this replacement of round tests by tests from finished material led engineers to ask for tests from finished pins, but such requests did not meet with encouragement from manufacturers, who opposed them on the grounds of expense and time. The engineer finally prevailed, however, and pins began to be tested, with results startling to some and disagreeable to others. The test from finished pins is now an established, though not a popular, custom.

Bridge pins are of two general classes, rolled and forged, and the change from one class to the other takes place at a diameter of about 6 ins. An ingot is rolled down to a bloom of convenient size, and this bloom is rolled or forged to the size ordered.

In the case of rolled pins the main consideration of the roller is to finish the pin truly round and of the required diameter and not break his rolls. This last consideration leads him to have the bloom heated as hot as may be without burning, and in consequence it happens frequently that some blooms are too hot and are burnt or overheated. Six-inch pins are often finished so hot that a bar 25 ft. long can be cut into 18-in. lengths on the hot saw. It will be seen from this that heat treatment and finishing temperature are refinements which stop short of rolled pins. These are generally made from the smallest blooms that are suited to the rolls and will finish to given diameters, and are finished very hot. In consequence, they lack work, both in reduction of section and finishing temperature, and are likely to be coarsely crystalline and deficient in toughness and ductility, if not absolutely brittle; see Tables Nos. 2 and 3.

The main reason for changing from rolled to forged pins at a diameter of about 6 ins. is a practical one. Existing rolls will not make a much larger size, and in the lengths in which they are rolled, they become difficult to handle. In making forged pins, the size of bloom is again the important consideration for the manufacturer. It must not be too large for the hammerman to handle conveniently in the heating furnace or under the hammer, and the result is that many so-called forged pins are little more than blooms with the corners knocked down. The weight, power and size of the hammer used for making forged pins have an important bearing on their final condition. For a small hammer a small bloom must be used, and it must

be made very hot. The blow from the small hammer on a large bloom is merely a surface blow, the work of which does not penetrate the metal to any extent.

With small hammers and large pins there is, then, a highly heated bloom, the shape of which is changed to a round by sliding the exterior over the interior without working the latter, and with the result of frequently rupturing the interior portions, especially if the bloom is not uniformly heated. The larger the hammer used for making forged pins, the better will be the results; larger blooms can be used, the work of the blow will penetrate deeper, they can be forged at a lower heat, and some attention can be given to the finishing temperature.

When pins first began to be tested, it was quickly discovered that the test nearest to the surface of the pin gave the best results, and that there was a constant falling off of quality as the test approached the center. It was also discovered that the size and shape of the test piece affected the results. Of two test pieces cut near the surface of a pin, one ¾ in. in diameter, and the other 1 in., the former will give the better results, and a flat, thin test piece in the line of a chord will give better results than either of the round pieces.

The most marked difference between the tests from pins and tests from shapes or plates is in the reduction of area and the appearance of the fracture. While the test piece from the surface of a pin may give a fair reduction of area with a fine, silky fracture, as the center is approached the reduction becomes decidedly less, and the fracture grows more coarse, irregular and cokey, until it may finally terminate with a crystalline fracture and little or no reduction. This change of appearance and loss of reduction indicates lack of work, too much heat, or both.

When pins are tested strictly with a view to ascertaining their quality, and not for the purpose of getting them past a specification, it is found that forged pins are better than rolled pins, and that the better the steel, the better the resulting pin, other conditions being the same. It is also found that a medium hard steel of about 70 000 lbs. ultimate strength will give better results than a soft steel. All pins are also improved by annealing.

From a consideration of Table No. 1, Cast A, it will be seen that even with an excellent quality of uniform steel, there is a falling off

of ultimate strength and physical properties as the center is approached. This may be ascribed to a lack of work and a high finishing temperature. Table No. 1, Cast B, shows the possibility of having highly segregated steel in a pin. In this pin the phosphorus and sulphur have doubled from the outside to the center, and from an excellent quality of steel the metal changes to a very ordinary quality. Had the cast analysis of this steel shown only an ordinary quality to start with, the steel at the center of this pin would have been dangerously defective.

Table No. 2 shows the generally poor results in a rolled pin made from common steel, and how the test may be improved by annealing. It may fairly be assumed that the pins themselves would also be improved by annealing. In this table, as in some of the others, there is what appears to be a paradox, namely, a rise in ultimate strength after annealing. This is undoubtedly due to a release of initial stress in the original pin by the annealing. A rise of ultimate strength, and an improvement of elongation, reduction and appearance of fracture after annealing are not confined to pin tests; the same phenomena are observed in eye-bars and other heavy sections. The initial stress may be readily caused by uneven heating or cooling.

Table No. 3 shows how un-uniform and treacherous it is possible for rolled pins to be. This steel is of a common quality, and not by any means as poor as much that is made. The analyses from the broken end indicate that it was approaching the zone of maximum segregation, but stopped short of it. From this table the improvement due to annealing may be again seen.

Table No. 4 shows the improvement in physical properties due to annealing the test piece, and, also, to even a crude annealing of the pin itself. It also shows that a good analysis does not alone insure good results. The blooms from which these pins were forged were so small that they received but little work, and were finished at a high heat.

From the foregoing it may be seen that bridge pins, even when made from a superior quality of steel, are not in a uniform condition; that the interior portions show a lack of work, and may show excessive segregation, which in steel of common quality is liable to reach a dangerous amount; it is also shown that pins are improved by annealing.

The following specification is submitted as being likely to procure as good bridge pins as can be had in common practice:

Bridge pins shall be made of open-hearth steel.

If made of acid steel, the cast analysis shall show not more than 0.06% of phosphorus, nor more than 0.03% of sulphur. If made of basic steel the cast analysis shall show not more than 0.03% of phosphorus, nor more than 0.03% of sulphur.

The manganese for either steel shall be not less than 0.5%, nor more than 0.8 per cent.

The smallest diameter of the final bloom or ingot to be made into pins shall be at least 50% greater than the diameter of the pin.

All pins shall be stamped with the cast number of the steel from which they are made, and shall be stamped with consecutive numbers from the bottom of the ingot to the top.

After pins have been manufactured to diameter, they shall be slowly and uniformly heated to a dark red heat in a suitable furnace, and left to cool slowly for a period of not less than 24 hours.

Tests cut from near the surface of annealed pins, and of a sectional area of not less than $\frac{1}{4}$ sq. in. shall have an ultimate strength of not less than 60 000, nor more than 70 000 lbs., per square inch, an elastic limit of not less than one-half the ultimate strength, an elongation in 8 ins. of not less than 20%, and a reduction of area at fracture of not less than 40 per cent.

Tests cut from near the center of pins shall comply with the above requirements, except that a fall of 5 000 lbs. in ultimate strength, and a fall of 5% in reduction of area, will be allowed.

The fractures of all pin tests shall be free from granulation.

Analysis of drillings taken from near the surface of pins shall not exceed the limits of the cast analysis by more than 10%, and, when taken from near the center, shall not exceed said limits by more than 50 per cent.

Tests and analyses shall be made on such pins as the engineer shall designate.

TABLE No. 1.—Tests from Acid Open-Hearth Steel Pins.

Nomenclature for Fractures.—C., Cup; Ck., Cokey; Cr., Crystalline; I., Irregular; S., Silky.

Cast.	Chemical Test. Percentage of elements. C.	P.	Mn.	S.	Test From	Physical Test. Stress, pounds per square inch. Elastic.	Ultimate.	Percentage of strain. Elongation in 8 ins.	Reduction in area.	Nature of fracture.
A	.22	.051	.39	.031	Cast analysis.					
"	.22	.049	.39	.030	10-in. forged pin No. 1.	37 780	62 550	20.7	50.0	Ck. ½C.
"	.22	.050	.40	.031	" " " No. 2.	37 800	58 780	19.2	43.0	" "
"	.28	.053	.39	.035	" " " No. 3.	36 570	56 140	22.5	37.7	" I.
B	.22	.053	.40	.038	Cast analysis.					
"	.24	.053	.44	.033	8-in. forged pin No. 1.	39 820	60 640	20.2	52.9	S. I.
"	.28	.062	.45	.039	" " " No. 2.	41 700	66 200	18.7	38.7	Ck. I.
"	.38	.105	.47	.078	" " " No. 3.	41 100	74 360	10.0	11.2	Cr.

Diagram of relative position of test pieces in pins. Pieces were turned to ¾in. diameter, and drillings for analysis were taken from them after breaking. Tests A were all from the same pin, and tests B were all from a second pin.

TABLE No. 2.—Tests of Acid Bessemer Steel Pins.

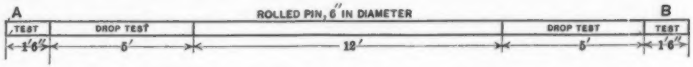
Nomenclature for Fractures.—C., Cup; Gr., Granular; S., Silky.

Cast.	Test From	Physical Test. Stress. Pounds per square inch. Elastic.	Ultimate.	Percentage of strain. Elongation in 8 ins.	Reduction of area.	Nature of fracture.	Remarks.
A	6½" rolled pin.	36 510	62 910	20.0	17.7	Gr.	Not treated.
"	" "	37 960	58 320	24.0	59.4	S. A.	Annealed in lime.
B	6½" "	37 800	60 320	13.2	11.3	Gr.	Not treated.
"	" "	38 080	60 250	28.0	61.1	S. ½ C.	Annealed in lime.
C	" "	38 100	57 480	8.7	15.0	Gr.	Not treated.
"	" "	41 180	62 800	26.2	62.2	S. C.	Annealed in lime.
D	" "	38 900	53 120	8.0	8.7	Gr.	Not treated.
"	" "	39 190	62 160	26.0	59.3	S. A.	Annealed in lime.

The above pins were made from an ordinary quality of steel, the chemical composition of which is unknown.

The first test in each group was cut from the pin as it was finished at the rolls; the second test was cut from the same pin and annealed in lime. The appearance of the fractures of annealed test pieces was excellent.

TABLE No. 3.—Tests of Acid Bessemer Steel Pin.



Nomenclature for Fractures.—A., Angular; C., Cup; Cs., Coarse; Fi., Fine; Gr., Granular; I., Irregular; S., Silky.

Chemical Test.				Test From	Physical Test.					Remarks.
Percentage of elements.					Stress. Pounds per square inch.		Percentage of strain.		Nature of fracture.	
C.	P.	Mn.	S.		Elastic.	Ultimate.	Elongation in 8 ins.	Reduction of area.		
.11	.103	.60	.061	End B, No. 1	39 710	62 780	27.0	38.8	S. ½ C.	Annealed in lime.
.11	.117	.60	.062	2	38 450	63 540	25.5	40.3	S. I.	" " "
.11	.110	.56	.060	(c) 3	35 020	59 460	13.8	12.2	Gr.	Not treated.
.10	.106	.61	.058	4	35 500	62 500	15.3	13.4	"	" "
.11	.120	.60	.062	(c) 5	32 850	56 400	11.3	8.8	"	" "
.10	.106	.62	.057	End A, No. 1	41 000	60 100	30.0	65.7	S. ¾ C.	Annealed in lime.
.10	.100	.60	.055	2	40 110	59 330	30.0	66.8	S. ½ C.	" " " "
.10	.104	.59	.055	3	31 520	56 350	29.5	49.3	Cs. Ck. I.	Not treated.
.10	.107	.60	.057	4	33 160	57 360	28.0	42.0	" " "	" "
.10	.114	.60	.055	5	29 840	55 300	30.0	45.5	" " "	" "

Above tests were 1 in. diameter.

BROKEN TESTS *c* AND *e* FORGED TO ¾-IN. SQUARES.

.11	.110	.56	.06	End B, No. 3.....	43 680	67 040	18.7	33.8	Fl. S. A.	Tests not annealed, but left with hammer temper.
.11	.120	.60	.062	5.....	45 600	67 440	21.2	40.7	Fl. S T.	

DROP TESTS.—WEIGHT OF DROP, 1 640 LBS.; SUPPORTS, 3 FT. APART; TEST PIECE REVERSED AFTER EACH BLOW.

	END A.				END B.			
Number of blow.....	1	2	3	4	1	2	3	4
Fall.....	25 ft.	25 ft.	25 ft.	25 ft.	15 ft.	20 ft.	25 ft.	29 ft.
Deflection.....	2 ins.	⅛ in.	2 ins.	Broken.	1⅛ ins.	¾ in.	1½ ins.	Broken.

The 6-in. round was rolled from an 8⅛ x 8⅛-in. bloom, which was rolled from a 15 x 18-in. ingot. The round had a short curve in the end B where the bar had followed the roll. An attempt was made to straighten this in a gag press, and at the first blow of the plunger the bar broke short off 1 ft. 6 ins from the end B.

The position of the test pieces in relation to each other and to the pin is shown in the diagram. The analyses were made from drillings taken from the broken test pieces.

TABLE No. 4.—TESTS FROM BASIC OPEN-HEARTH PINS.

Nomenclature for Fractures.—A., Angular; C., Cup; Ck., Cokey; Gr., Granular; S., Silky.

CAST.	CHEMICAL TESTS. Percentage of elements. C.	P.	Mn.	TEST FROM	PHYSICAL TEST. Stress, pounds per square inch. Elastic.	Ultimate.	Percentage of strain. Elongation in 8 ins.	Reduction of area.	Nature of Fracture.	REMARKS.	
A	.29	.031	.63	6¼-in. forged pin.	37 620	67 840	25.0	36.7	Ck. C.	Not treated.....	Size of test. ⅞ in. diameter.
"	Cast a	nalys	is	" " ..	40 640	67 300	18.0	30.2	" ½ C.	"	1½ in. "
"	.....	.....	.....	" " ..	40 000	72 200	18.0	28.4	Gr.	" .....2 x ½ in.	
"	.....	.....	.....	" " ..	36 760	68 520	22.7	49.0	S. ½ C.	Annealed in lime.....	⅞ in. diameter.
The above tests all from the same pin, forged from an 8⅛ x 8½-in. bloom.											
B	.29	.032	.52	6¼-in forged pin...	39 510	67 350	20.0	30.0	50⅝ Gr.	Not treated.....	1 in. diameter.
"	Cast a	nalys	is ...	" " ..	35 790	64 620	28.2	49.9	S. ¾ C.	Annealed in sand.....	1½ in. "
"	.....	.....	.....	" " ..	39 530	66 150	26.2	41.9	S. A	" "	" "
C	.29	.032	.53	6¼-in. forged pin..	39 220	68 560	20.0	27.7	75⅝ Gr.	Not treated.....	1 in. "
"	Cast a	nalys	is	" " ..	38 160	65 270	26.5	43.6	S. A.	Annealed in sand.....	1½ in. "
"	.....	.....	.....	" " ..	39 490	66 280	26.5	48.0	S. ¾C.	" "	" "

Tests marked, "not treated," were cut from pins as finished by the hammer. In casts B and C, the second and third tests in each group were cut from pins which, after being forged, were reheated to a red heat and buried in dry sand for 24 hours.

DISCUSSION.

Mr. Metcalf. WILLIAM METCALF, Past-President Am. Soc. C. E.—The paper is of great value, as it gives important information which engineers cannot obtain otherwise, unless they are familiar with the practice of steel manufacture. The dimensions and right use of the rolls and the hammers are important matters in making pins and in all forging. They may be large enough, but the work done may be too light to penetrate the mass of the metal as it should. There is one simple means by which the inspecting engineer can always determine whether the work has penetrated the mass or not. If the finished bar or forging has concave ends, the outside material has simply been drawn over that inside, the work has not penetrated the mass, and a bad state of affairs results, as mentioned in the paper, from too little rolling or too little hammering. When a bar comes out practically straight or rounded on the end, the work done upon it has been sufficient to penetrate the softer material in the center. When the ends are convex, the work is complete so far as the forging or rolling goes.

The weight of the hammer is very important. The rule in ordinary practice is that a 1 000-lb. to 1 200-lb. hammer should never be used on a section larger than 1½ ins. square. From 1½ to 3 ins. a 2 000-lb. hammer will do very well. Between 2 and 3 ins. a 2 000-lb. to 2 500-lb. hammer ought to be employed, while for such work as bridge pins up to 6 ins. in diameter, a hammer weighing at least 3 tons is necessary to do the work properly.

Bursting is a more serious danger than piping in hammering round pins. If a piece is hammered too heavily with flat dies, the center is bound to burst. This effect of radial work is emphasized and illustrated in the Mannesmann process of heavy radial rolling, by which means a hollow tube is produced from a solid billet. If the dies are shaped so as to offer three supporting surfaces to the bar, or if the piece is first knocked into a rough octagon and then swaged in grooved dies, it is extremely difficult to burst a pin. Engineers should refuse to accept a pin forged under flat dies, since it requires the highest degree of skill to produce a sound round section in this way.

The author specifies that annealing should be done by heating the bar to a dark orange red, usually called cherry red, and leaving it in the furnace for 24 hours. This is a dangerous practice for the reason that it is not always sure the furnace will remain at its final heat for this time. Radiation may make the furnace still hotter, when the long-continued heating with slow cooling will cause a separation of the carbon from the steel, produce a granular condition of the metal and weaken the steel greatly. It is preferable and all-important in

the annealing to heat the bar a little higher, to a fair, medium orange color, and the moment it is heated through, to bury it in either warm ashes or sand, where it will cool slowly. After a pin is forged, if it be heated thoroughly to a fair, medium orange color, about 1 100° Fahr., all of the coarse grain in the center will become as fine as the finest part of the steel. If the heat is uniform, the grain will be uniform. If a piece be taken from the fire as soon as it is heated through uniformly to a medium orange color and cooled slowly, it will have a fine grain and be free from all strains, and the carbon will remain in solution, which is its best condition. Long-continued heating of any steel will cause carbon to separate out in the mass into a graphitic form, and in that condition it is of no more use than so much sand. Mr. Metcalf.

Silicon up to 0.2% may be allowed because of its value in reducing blow-holes; but, if steel be sound, the lower the silicon the better, as its tendency is to cause brittleness. There need never be any good reason for more than 0.2% silicon, and there ought not to be a necessity for so much. The maximum limit of manganese should be 0.5 and the minimum as low as possible, because manganese is useful only as a reducer of oxides; it is not otherwise a valuable constituent in steel. In a specification for crank pin steel for locomotives, there occur the same chemical limits as those in the specification given in the paper, except that a maximum limit is provided for manganese, but the physical specification is that the pins shall have not less than 85 000 lbs. tensile strength, nor less than 15% extension in 8 ins. There is no difficulty in making open-hearth steel having 0.6 carbon with 95 000 lbs. tensile strength and 15% extension. Such steel should be annealed to give it uniformity. If crank pins, which have to withstand the severe strains of locomotive service, are better at this higher specification, it is hard to see why bridge pins, which are not subjected to such severe strains, would not be better if made under similar specifications.

Boring the pins in the manner specified by Past-President Morison will either remove the burst or enable the defects to be seen. The removal of the core of the pins in this way does not weaken the steel.

CORRESPONDENCE.

Mr. DeForest. GEO. T. DEFOREST, Assoc. M. Am. Soc. C. E.—The writer fully agrees with the author as to the unreliability of reports on shape tests showing the condition of steel in pins, and as the trouble seems to be caused by the manipulation of the material he does not think tests of pin material particularly valuable except in that they show quality rather than condition of material used.

A few years ago the writer had an experience with some 7 and 10-in. pins. The material was made under a mild steel specification (open-hearth or Bessemer) with an ultimate strength of 60 000 to 68 000 lbs.; elastic limit, 37 500 lbs.; and elongation, 22%; steel in pins to be sound. No chemical analysis was required. These pins were, of course, forged, and while the writer was not connected with the inspection at the mill, he knows they were made in a mill where there are all the best facilities, both for heating and forging. Apparently a great deal of work was put on them as they were nearly perfect as to roundness.

They came to the shop, after inspection at the mill, cut by saw to approximate lengths. When pins were turned up and cut to length in the lathe it was noticed that the centers were badly segregated in about one-quarter of the 7-in. pins, while of the 10-in. pins five out of ten were in this condition, in some cases the segregation apparent to the eye being 1 in. in diameter, and in the one pin experimented on by drilling it seemed to run the entire length of the pin.

This seems to show the utter unreliability for showing condition of material in pins of the ordinary tests and inspections at the mill, and would also seem to indicate the necessity of separate treatment for each pin, namely, a very thorough surface inspection while the lathe work is going on in addition to the physical and chemical analysis, or better still, to adopt the clause in the specifications of one eminent bridge engineer that "all pins shall be drilled through their axes," which certainly ought to show the condition of the material at the center.

Mr. Morison. GEORGE S. MORISON, Past-President Am. Soc. C. E.—The principal point developed in the paper is one which is very important, but is not new. It has been long recognized that pins do not receive the work in manufacture which smaller sections do, and are, therefore, not as uniform and good a material. It has also been known that large rolled pins were generally of inferior character, and that if large pins were forged under light hammers, piping was usually found on the axes.

The writer's attention was called to the existence of piping in pins some years ago, and a little reflection showed that when piping did not

actually exist, the same circumstances which had produced it in one pin were likely to have produced a very inferior material at the center of another pin. The case is analogous to steamship shafts where the difficulty is removed by longitudinal boring. If the same defects and strains exist on the axis of a bridge pin which exist on the axis of a large shaft, it seemed to him that the method which has successfully relieved this difficulty in shafts could be applied with advantage to bridge pins. Mr. Morison.

Accordingly he incorporated in the specifications for the Cairo Bridge, which were dated March 23d, 1887, the following clause:

"Steel for pins shall be sound and entirely free from piping. All pins more than 4 ins. in diameter shall be drilled through the axes."

The same clause was inserted in the specifications for the Sioux City and the Nebraska City Bridges, which were built about the same time, as well as in the specifications for the Riparia and Jacksonville Bridges which were built a year or two later. In the specifications for the Memphis Bridge, where some of the pins were exceptionally large, the following clause was inserted:

"Steel for pins shall be sound and entirely free from piping. All pins in the main trusses shall be annealed before they are turned and shall be drilled through the axes."

At first, manufacturers objected to this drilling, but the difficulties disappeared when the work began. The first manufacturer drilled the pin from both ends and exhibited a little flat disc which came out on the completion of the second cut, as evidence of the accuracy of his work.

The hole through the axis was used to pass a bolt through to hold washers at the ends of the pin, thus avoiding the necessity of tapping the pin for nuts. This, however, is not a necessary feature of the drilled pin, and nuts of the common form can be used.

The writer's experience with drilled pins has been such as to convince him of the importance of the practice. In one bridge the drilling revealed a great deal of piping and caused the rejection of nearly all the pins that were first made. It appeared that these pins had been forged under a light hammer which was worked with a large steam pressure on the downward stroke, and when he inquired the weight of the hammer, an equivalent weight was given to him instead of the real weight, the force of the steam being added to the weight. It is the mass of matter in the hammer and not the force of the blow which determines the penetration of the effect.

The writer believes that a proper specification would contain a provision fixing a minimum weight of hammer for each diameter of pin, but he has not yet satisfied himself as to what this weight should be; it should probably be a multiple of the cube of the diameter. In his latest specifications he has omitted the requirement for drilling on the

Mr. Morison. axis, but has done so simply because it seemed to him a feature which was more properly shown on the plans than in the specifications. In specifications which are drawn for manufacturers who will make their own plans it should always be inserted.

On one occasion the manufacturer saw fit to drill the pins with a hollow tool which left a solid core taken directly from the center of the pin; this manufacturer has a very heavy steam hammer under which these pins were forged and no defects were revealed even in this core. The fact that such a core can be made without serious difficulty, the manufacturer in this case doing it voluntarily without request, provides a method for testing pins in the most rigid way.

Mr. Cunningham. A. C. CUNNINGHAM, M. Am. Soc. C. E.—The correspondence on this subject illustrates in a forcible manner the variation in results due to an ordinary specification and inspection, and a special specification rigidly enforced.

The specification quoted by Mr. De Forest admits any of the general kinds of steel, without chemical limitations, with a moderate elongation and no reduction of area. It is the kind of a specification that a manufacturer glances at but once, and after noting on the order "Use stock steel, 60 000 to 68 000," places in his files to be forgotten.

Although not mentioned by Mr. Morison, his specifications contain, besides the special requirements for pins quoted, chemical limitations for the steel, with full, complete and rigid physical requirements. This is the kind of a specification that the manufacturer keeps in his pocket for constant and ready reference.

Under the first specification it will be seen that from one-quarter to one-half of the pins sent to the bridge shop show visible defects, and what their chemical defects may have been is a matter of conjecture. Under the second set of specifications there were, at first, objections on the part of manufacturers, a misleading statement, and the rejection of nearly all the pins that were first made. Then follows compliance with the requirements, improvements in the requirements themselves, and finally the manufacturer voluntarily doing more than was required of him. A more forcible demonstration of the value of a good specification and rigid supervision could not well be found.

As the matter of segregation has much prominence in this paper, it may be well to describe it for the benefit of those who have not given it attention up to the present time; it is, of course, not new, but is very important.

When steel is first cast into an ingot mold it is in a uniform condition chemically, provided the carbon, manganese, silicon, or whatever else may have been added to it when it was tapped from the furnace, has been thoroughly mixed with it. That the paper sacks of powdered charcoal, or the coarse and cold chunks of spiegeleisen, ferro-manganese or ferro-silicon that are sometimes thrown or shoveled

haphazard into the ladle, are thoroughly mixed is an open question, and irregularities due to this cause must not be confounded with segregation. Mr. Cunningham.

The liquid and chemically uniform steel in the ingot mold begins to cool and solidify from the outside toward the axis, from the bottom towards the top, and, to a less extent, from the top downwards.

When this process of cooling and solidifying begins, some of the substances associated with the steel commence to move toward the more liquid portions, to segregate or separate out. Of most importance among the segregating compounds are those of carbon, phosphorus and sulphur. These are moving in the lines of cooling or toward the axis and upper part of the ingot. The entire amount does not move; some is retained where it was first located, and the increase from the first solidified portions to the last is gradual. The part of the ingot which sets last is probably shaped somewhat like an inverted cone. It is on the axis of the ingot and in its upper third, and in this portion will be found the greatest segregation.

The amount of segregation which takes place in an ingot depends upon its size, shape, temperature of steel when cast, rate of cooling, and amount of segregating compounds contained in the steel. The quicker the steel solidifies, the less will be the segregation. The smaller the amount of segregating compounds in the steel, the less the tendency toward segregation. Segregation is not always found and, when found is not always excessive, though cases have been noticed where phosphorus and sulphur have doubled or even more between the outside of an ingot and the axis.

The suggestions contained in the discussion of Mr. Metcalf are of such value and importance that it will be well to incorporate most of them in the specification.

The medium orange color recommended by Mr. Metcalf for annealing is the heat of recalescence, so admirably and clearly described in his new work "Steel," at which steel assumes its finest grain and retains it if heated no higher. Very high authorities state that manganese is not only a reducer of oxides in steel, but is a neutralizer of the ill effects of phosphorus and sulphur, by preventing the coarse crystalization which they tend to produce; also that it makes steel more plastic when hot, and renders it capable of standing high heats without injury. The book by H. H. Campbell, M. Am. Soc. C. E., entitled "Structural Steel," is the latest authority which inclines to these views of manganese.

It is a matter of history that steel was not a commercial success until manganese was incorporated in it. It is also a matter of history that in the early manufacture of steel, manganese was used in excess to cover up bad practice and bad chemistry. The enemies of manganese call it a "cloak for sins," but they also want a little in steel;

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its friends might as consistently call it a poultice for evils, but at the same time they do not want too much.

Manganese makes steel brittle, especially when quenched or hardened, but the upper limit in this specification is not an excess for the grade of steel specified, and this steel is to be annealed and not hardened. The lower limit is needed to insure the qualities which it has been mentioned that manganese imparts, and a good steel maker working under this specification should produce a steel with from 0.55% to 0.6% of manganese. Steel rails which are a much harder and a much poorer kind of steel than this specification provides for, contain from 0.8% to 1% of manganese. Manganese does not segregate, and even if the upper limit of the specification is reached, it will not exist in any greater amount in any portion of the steel.

The crank-pin steel mentioned by Mr. Metcalf might make excellent bridge pins if the pins were forged, annealed and worked with the same care as crank pins. The bridge pin steel, however, would not do for crank pins, which must have great rigidity to keep the size within bounds and to resist the great bending stress due to their being fixed at only one end; resistance to abrasion is also an important quality in a crank-pin.

Whether the expense of boring an axial hole through the entire lot of pins for a bridge to determine their solidity is warranted or not is open to question. The piping which may form when an ingot is cast can and should be all cut away, and it would be a bad case, indeed, in which it extended more than one-third the way through an ingot. Moreover, these pipes or the bursts due to bad forging or segregated steel, which are sometimes mistaken for pipes, are not necessarily on the axis.

If there is a pipe proper in a pin or an extensive burst, the machine finishing of the end in a lathe will reveal it. If a burst does not reach either end of the pin, an axial hole may pass within less than a quarter of an inch of it without revealing it.

The following revised specification for bridge pins is submitted :

Specification for Bridge Pins.

1.—Bridge pins shall be made of open-hearth steel.

Note.—Open-hearth steel is specified on account of its known superiority to Bessemer.

2.—If made of acid steel, the cast analysis shall show not more than 0.06% of phosphorus, nor more than 0.03% of sulphur. If made of basic steel the cast analysis shall show not more than 0.03% of phosphorus, nor more than 0.03% of sulphur.

Note.—Acid and basic steel are placed in competition, and as the basic process is essentially a dephosphorizing one, the lower phosphorus is specified in order that there may be competition; and if

basic steel is used, the purchaser may have the benefit of the lower phosphorus. The phosphorus and sulphur limits for both steels are made such that if segregation takes place and is not discovered, it is not likely to be dangerous. Mr. Cunningham.

3.—The manganese for either steel shall not be less than 0.5%, nor more than 0.65 per cent.

NOTE.—These limits are higher than open-hearth practice for plates and angles. The pins will be heated several times during manufacture, perhaps unevenly and perhaps very hot, and these limits, which are well within the point of safety, are specified in order that the pins may stand such treatment with the least injury.

4.—The smallest diameter of the final bloom or ingot to be made into pins shall be at least 50% greater than the diameter of the pin.

NOTE.—This smallest size of bloom or ingot is specified in order to secure not less than a certain amount of work in finishing the pin.

5.—Whether rolled or forged the crop ends of all pins shall have a convex end.

NOTE.—The convex end for crops is to secure sufficiently heavy hammer or rolls to have the work penetrate the entire pin.

6.—Forged pins shall be made with concave dies of a form satisfactory to the engineer.

NOTE.—Concave dies of the correct form are least likely to burst the steel.

7.—All pins shall be stamped with the cast number of the steel from which they are made, and shall be numbered consecutively from the bottom of the ingot to the top.

NOTE.—The consecutive numbering is in order that pins may be readily selected for segregation tests.

8.—After pins have been manufactured to diameter they shall be carefully and uniformly heated to a medium orange color in a closed furnace out of contact with the fuel, after which they shall be buried in warm dry sand or ashes until cool.

NOTE.—Pins are annealed to remove any initial stress that may be set up, and to give them a uniform, fine structure.

9.—Tests cut from near the surface of annealed pins and of a sectional area of not less than ¼ sq. in. shall have a maximum strength of not less than 60 000 lbs., nor more than 70 000 lbs. per square inch, an elastic limit of not less than one-half the maximum strength, an elongation in 8 ins. of not less than 20%, and a reduction of area at fracture of not less than 40 per cent.

Tests cut from near the center of pins shall comply with the above requirements, except that a fall of 5 000 lbs. in maximum strength, and a fall of 5% in reduction of area will be allowed.

NOTE.—This grade can be readily made in acid or basic steel. The variation between the surface and center is allowed on account of

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the natural falling off in physical properties as the latter is approached.

10.—The fractures of all tension tests shall be free from granulation.

NOTE.—Granulation indicates poor work, poor heating, or poor annealing.

11.—Tests cut as before specified shall bend, at the normal temperature, 90° around a diameter equal to the thickness of the test, and between a dark red and a light yellow heat, 180° flat on themselves, all without rupture on the outside of the bent portion.

NOTE.—These bends are a protection against cold and hot or red short steel.

12.—Analyses of drillings taken from near the surface of pins shall not exceed the limits of the cast analysis by more than 10%, and, when taken from near the axis, shall not exceed said limits by more than 50 per cent.

NOTE.—This puts a safe limit on the allowable segregation.

13.—Tests and analyses shall be made on such pins as the engineer shall designate.

NOTE.—Pins being numbered consecutively from the bottom of the ingot, the engineer will be able to select those most likely to contain segregation.